High Output Power for Hydrogen Maser Frequency Standards

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This article describes the use of an FEP and TFE Teflon mixture to form duplicable storage bulb wall coatings for hydrogen maser frequency standards. The use of this mixture has resulted in wall coatings more efficient than previous coatings fabricated at this facility. A hydrogen maser has been optimized for high-power operation using these new storage bulbs, and a power output level of −80 dBmW has been achieved.

I. Introduction

The frequency stability of the atomic hydrogen maser frequency standard is primarily dependent upon the linewidth of the atomic hydrogen zeeman transition. This linewidth in turn depends upon how long one can store a spin-excited hydrogen atom within the magnetic field of a microwave cavity without losing energy to one of several collision processes. In hydrogen masers, atoms are "stored" in a quartz sphere located in the center of a TE_{011} microwave cavity. This provides a spatially uniphase field to a majority of the atoms within the sphere. Hydrogen atoms are beamed into the sphere from a collimated source and the aperture of this sphere is adjusted to limit the escape rate of these atoms. Hence, the average time an atom spends under the influence of the microwave field can be adjusted for best tradeoff between maximum attainable output power (short storage times) and long-term frequency stability (long storage times). The storage sphere wall must be coated with a material that will not disturb the phase "memory" of stored hydrogen atoms which collide with this surface. Teflon coatings have been most successful for this purpose.

II. Storage Bulb Coating Process

Fabrication of a Teflon coating which is free of pinholes and other imperfections has proved very difficult. These imperfections are deleterious to the storage process, and result in a loss of hydrogen maser output power. Although multiple coatings of the same storage bulb have helped minimize these imperfections, the extent of the difficulties encountered has caused some workers to ascribe the term "vintage year" to certain batches of Teflon raw material.

FEP Teflon coatings have been used in the majority of hydrogen maser work. While our experience has shown a "good" TFE Teflon coating to be superior to a "good" FEP Teflon coating, the former is more difficult to obtain. Other workers in the field have also confirmed this fact.

Considering the chemical structural properties of both FEP and TFE Teflons, it was decided to evaluate coatings made from a mixture of these two materials. Preliminary results with our laboratory maser show that very efficient coatings can be made from a mixture of TFE and FEP, and that although neither material could individually be made to produce an efficient coating, the combination in one single coat produces a surface which additional recoatings have not improved upon. The coatings resulting from this new process have been the most efficient produced to date at this facility.

The mixture used in these tests was 5 parts of FEP to 1 part TFE and 2 parts water. The bulb surface is coated with this mixture, dried, and subsequently baked under carefully defined laboratory conditions.

III. Increased Maser Output Power

Use of this new storage bulb coating technique in the JPL hydrogen maser resulted in saturated output power at flux levels which previously were in an unsaturated region. This indicated the possibility of achieving higher maser output power levels by optimizing microwave cavity coupling and storage bulb parameters.

Figure 1 shows the results of changing the storage bulb aperture diameter. The curves represent maser output power versus the total hydrogen flux into the vacuum chamber (measured as vacuum pump ion current). The cavity coupling coefficient was varied with an external tuner to optimize output power level for the various aperture diameters tested.

An interesting result of high-power operation is that the cavity pulling factor—an important quantity in long-term frequency stability considerations—has not changed significantly from that for low-power operation. The increased atomic linewidth caused by opening the storage bulb aperture from a 6.3- to 11.9-mm diameter has been largely offset by a reduction in optimum loaded cavity Q from 47,000 to 32,000. The net effect is that long-term frequency stability should be similar to that achieved at lower power output levels. The short-term frequency stability, which depends upon maser output power overcoming followup receiver noise, should also be improved with high-power operation.

IV. Present Testing

Present testing is limited to a single laboratory maser. The performance improvements and operating characteristics attendant to high-power maser operation will be further explored using the prototype masers now in operation at Goldstone.

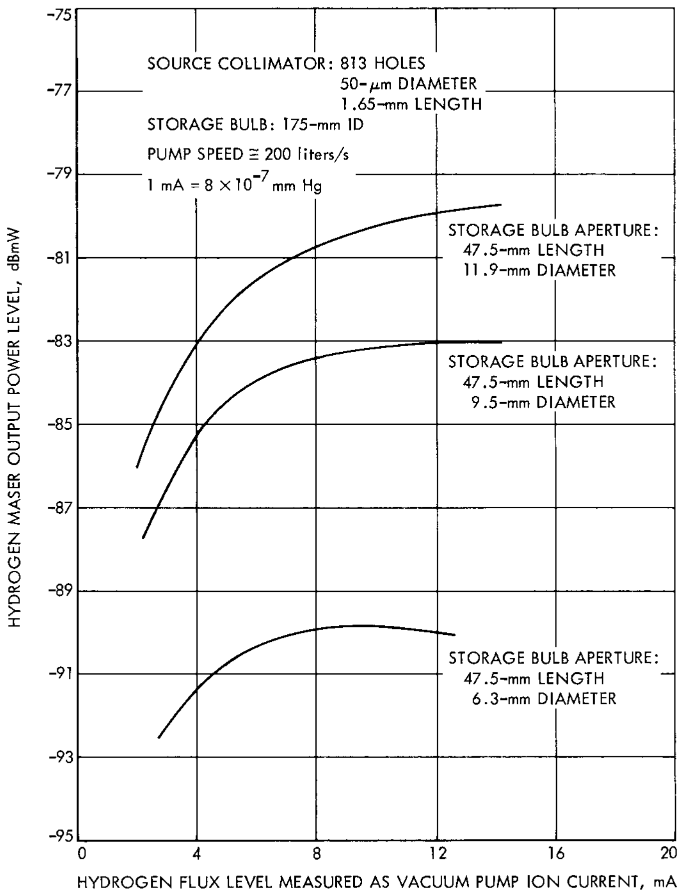

Fig. 1. Hydrogen maser output power vs storage bulb aperture using new process storage bulbs